Experimental Study on Enhancement of Heat Transfer in Concentric Tube Heat Exchanger by Providing Inserts on Both Sides of Inner Tube

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***Abstract*— There are a number of heat transfer enhancement techniques to enhance the rate of heat transfer without affecting much the overall performance of the system. Those techniques are broadly classified into active and passive techniques. Passive techniques are the methods used to enhance heat transfer rate without the use of external power. Inserts, Extended surface, Surface modifications, Use of additives are the generally used passive methods. Inserts refers to the additional arrangement made inside the tube which act as an obstacle for the fluid flow. A lot of research work has been carried out in this field by adopting different shapes of inserts. Most of them have shown there can be a remarkable increment in heat transfer. Among those researches most of them have mainly concentrated on keeping inserts in the heating part of the heat exchanger. In present work the concentration is made in the heat exchanger part where cooling of working fluid takes place. Wire coil inserts are fitted on both sides of the inner tube of concentric tube heat exchanger and the enhancement in the heat transfer rate is analyzed**

***Index Terms*— Heat transfer coefficient, Inserts, Extended surface, Heat exchanger.**

I. Introduction

The enhancement of heat transfer in heat exchanger has become an area of interest in many engineering applications like process industry, thermal power plants, refrigerators, automobiles, etc. There are a number of experiments that has been done in order to find out the cost effective heat transfer enhancement techniques and to reduce the size or complexity in design. In simple words techniques for enhancing heat transfer implies improving and intensifying the thermal performance of a heat exchanger. Existing heat transfer enhancing technologies mainly falls under two categories.

i. Active technologies- it includes the supply of external energy to the fluid or equipment in order to obtain the flow modification and thus the enhancement in heat transfer. Several studies have been done in active augmentation but because of the complexities in design and due to the difficulty in supplying external energy in several applications it haven't got much popularity.

ii. passive technologies- it comprises of technologies which doesn't use external power for enhancing heat transfer but uses the available power in the system. Extended surface, tube inserts, wire mesh inserts are the most important passive technologies among which tube inserts using wire coil inserts and twisted tapes are the widely used than other techniques. They increases heat transfer coefficient by altering or disturbing the flow behavior by inserting additional arrangements. Because of no modification needed in the actual system they have widely accepted the usage of tube inserts in several applications.

Heat exchanger is one of the inevitable devices in a thermal industry, which finds its very uses in transferring heat from hot fluid to cold fluid which intern increases the thermal efficiency. One of the major difficulty arises in the usage of heat exchanger is fouling mitigation. By the difficulties occurring on redesigning or adding anti fouling additives to the existing heat exchanger in many cases the only solution is to clean the exchanger in regular intervals that causes high maintenance cost. Tube inserts are used as a solution for this problem.

II.EXPERIMENTAL SET UP

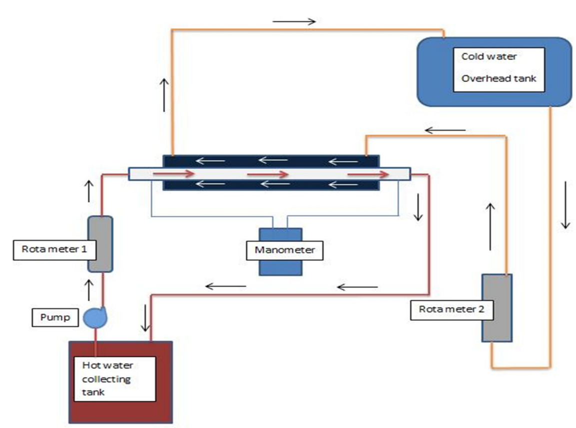

Fig 1.Schematic diagram of experimental set up

The setup is a double pipe heat exchanger consisting of a test section, rotameters, manometer, overhead tank for supplying cold water, hot water collecting tank, electric water heater, pump and control valves and other pipe fittings. The test section consists of a smooth aluminium tube of 21.3 mm ID and 25.4 mm OD and a length of 1.5m. The outer pipe is made up of PVC pipe of 38 mm ID and 40 mm 1.4 m. Due to the addition of T joints and other fittings effective heat transfer area is considered as 1.34m. In order to avoid the extra arrangement for insulation outer pipe itself is selected as PVC pipe which is a best insulator. Two calibrated rotameters which gives flow ranges from 200 LPH to 1080

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LPH are used to measure the flow rates of cold water inlet and hot water inlet.

Cold water is taken from the overhead tank using gravity flow. A globe valve arrangement is given just before the rotameter inlet in order to regulate the flow. The cold water flow rate is maintained at 900 LPH to maintain fully developed flow through the annulus. In the hot water side a bypass arrangement is provided just before the rotameter to control the flow from pump instead of providing valve arrangement. This is done by considering the pump power which is sufficiently large enough to make damage to the set up if we use the valve arrangement without bypass. Immersion coil heating element of 1.5 kW is used to heat the water. 0.5 HP pump of 3m head and 1250 LPH discharge is used to pump this hot water into the heat exchanger. For measuring the pressure drop in the test section two pressure tapings , one just before the test section and another just after the test section are provided. These tapings are connected to u tube manometer which uses mercury as working fluid to measure the pressure difference. Four k type thermocouples which can measure up to 200°C are used to measure the inlet and outlet temperatures of hot and cold water. These thermocouples are connected to a multipoint digital temperature indicator.

Fig 2. Experimental set up

Wire coil insert used for the experimental study is made up of galvanized iron considering its low cost, availability and flexibility in twisting as coil. Sufficient length of the wire has selected for making wire coil of length 1.4 m. A reference pipe is selected which has an outer diameter same as the inner diameter of inside pipe and pitch is marked on the pipe. GI wire has been wrapped through this marking and wire coil of diameter same as inner diameter of inside tube is obtained. Before installing the insert is stretched a little bit to make easiness in installing and to enable the firm contact of insert with the inner surface of inner tube. With the help of GI straight long wires insert is installed in position and extra portions has been cut out.

Fig 3 GI wire coil inserts used in the experiment, p = 30mm, l=1.4m

III.STANDARD EQUATIONS USED

Friction factor, for Re > 2100, Colburn's equation,

$$f = \frac{0.046}{Re^{0.2}}$$

For turbulent condition, Re > 10,000 Dittus - Boelter equation is used

$$Nu = 0.023 \times Re^{0.8} \times Pr^{n}$$

Wilson plot has been used to find experimental heat transfer coefficient

$$\frac{1}{Ui} = \frac{1}{A \times Re^{0.8}} + K$$

Where K is a constant found from Wilson plot ($1/Ui$ vs. $1/Re^{0.8}$).The intercept gives value of K.

IV.RESULTS AND DISCUSSION

i) HEAT_TRANSFER

Heat transfer has been increased when insert is fitted. It is increased even more when insert is fixed on both sides of the tube. As the Reynolds number increases the difference between heat transfer rate of smooth tube and tube with insert has found to be decreasing. This may be due to the less effect of insert to create turbulence in the high Reynolds number region since the flow is already in high turbulent condition. In the case of both side insert an increase in the heat transferrate in an almost constant value is found as the flow rate increases.

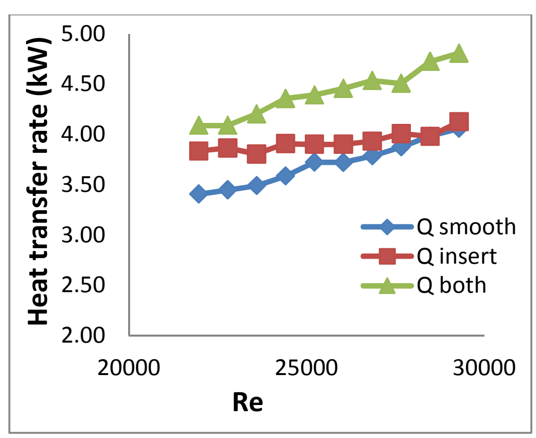

Fig 5 Heat transfer rate vs. Reynolds number

From the figure 6 it is clear that there is only a small difference between the heat transfer coefficients calculated by using correlations and experimentally found values. This variation might be due to the limitation of the experimental set up.

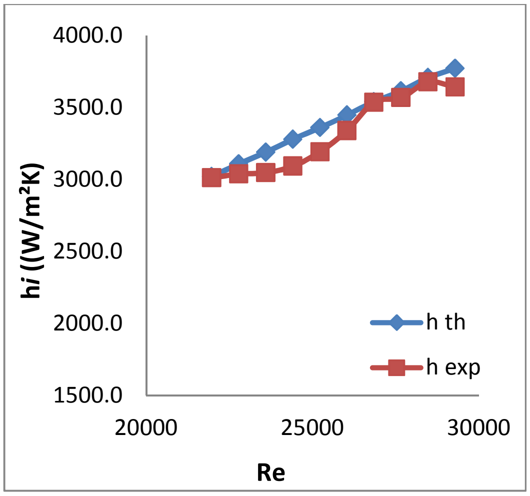

Fig 6 Heat transfer coefficients v/s Reynolds number for smooth tube

Fig 7 shows the variation of experimentally calculated heat transfer coefficient and heat transfer coefficient calculated using correlations. A positive error of average value 2.652 % is found on experimental values.

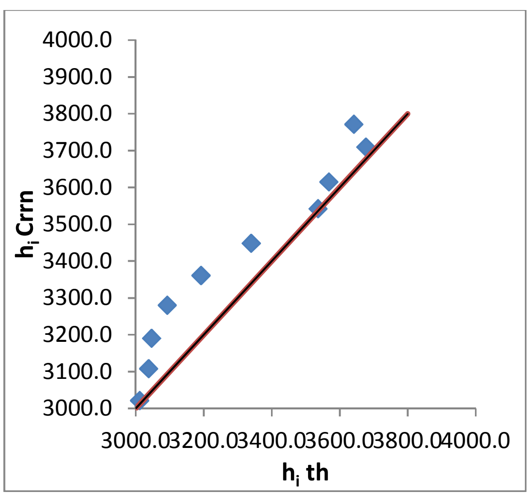

Fig 7. h experimental v/s h calculated using correlations

Fig 8 shows the comparison of inside heat transfer coefficient of smooth tube and tube insert. From the graph it can be observed that heat transfer coefficient has been increased 1.2 times for tube inserts. This enhancement in tube insert is due to the turbulence effect created by the wire coil. Since the insert has been fixed firmly to the surface it prevents the formation of boundary layer near the surface. These two effects thereby increase in tube wall temperature causes heat transfer to increase. Since all other parameters are same it can be concluded that this increment in heat transfer is due to the enhancement in heat transfer coefficient.

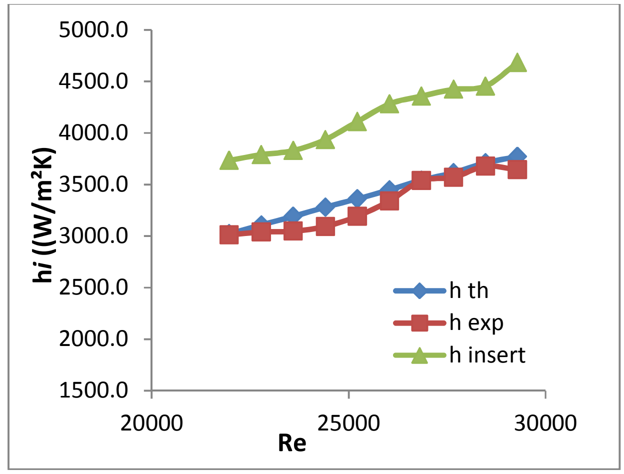

Fig 8 Heat transfer coefficient vs. Reynolds number for smooth and tube insert

As the flow rate of cold fluid which was flowing through annulus has kept constant for the set of experiments outside heat transfer was found to be a constant value. The outside heat transfer coefficient for the tube with both sides insert is found to be increased 1.4 times from the coefficient of smooth tube. The increment in outside heat transfer coefficient was found to be slightly higher than increment in inside heat transfer coefficient. This may be due to the position of insert placed. The inside insert has been fixed near to the wall and the outside insert is in the core section of annulus. Altering the core flow gives more effects.

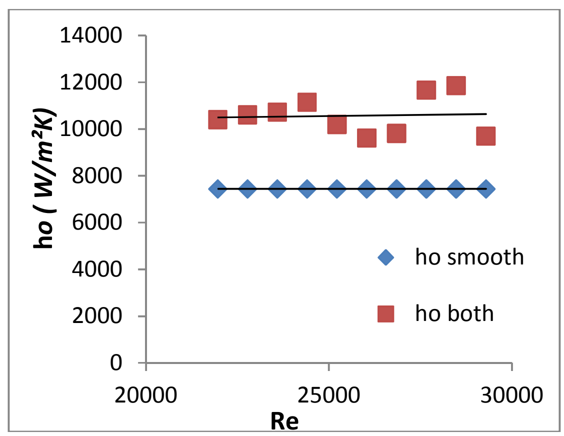

Fig 9. Outside heat transfer coefficient v/s Reynolds number for smooth and both sides insert

ii) <u>FRICTION FACTOR:</u>

Friction factor has been increased for tube with insert. As insert is inserted inside the tube the pressure drop increases because of the flow obstruction caused by the insert and so the friction factor increases. As Reynolds number increases the friction factor is found to be decreasing

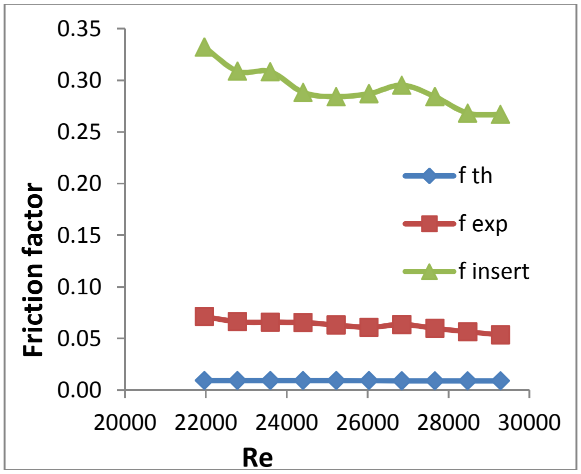

Fig 10 Friction factor vs. Re for smooth tube and tube insert

V.CONCLUSION

An experimental study on enhancement of heat transfer in concentric tube heat exchanger by providing inserts on both sides of inner tube has been carried out. From the study it is found that by the application of inserts heat transfer has been increased up to 20%. Insert fitted in the flow path has mainly two effects in the enhancement to heat transfer. It creates turbulence in the flow and prevents the development of boundary layer. Because of these two effects the inside heat transfer coefficient has increased 1.2 times and the outside heat transfer coefficient has increased 1.5 times. With increase in Reynolds number the effect of insert has found to be decreasing slightly. Friction factor also increases as the turbulence created by the insert increases. So insert can be used in applications to effectively enhance the heat transfer without changing the whole system or increasing mass flow rate where a relaxation to the pressure drop is allowed.

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